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I also certify that the attached copy of the request for grant of a Patent (Form 1/77) bears a correction, effected by this office, following a request by the applicant and agreed to by the Comptroller-General.

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Request for grant of a patent

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1.	Your reference	XLT 85b
2.	Patent application number *(The Patent Office will fill in this part)*	0315848.2
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	<u>HEAD</u> PHILIP GIBB HOUSE KENNEL RIDE ASCOT BERKS SL5 7NT
	Patents ADP number *(if you know it)*	7920812001
	If the applicant is a corporate body, give the country/state of its incorporation	UNITED KINGDOM
4.	Title of the invention	ELECTRIC MOTORS FOR POWERING DOWNHOLE TOOLS
5.	Name of your agent *(if you have one)*	
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	HILLGATE PATENT SERVICES NO. 6 AZTEC ROW BERNERS ROAD LONDON N1 0PW
	Patents ADP number *(if you know it)*	5953112002

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	GB	0221630.7	18/09/02

		Number of earlier application	Date of filing *(day / month / year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	~~0221630.7~~	~~18/09/02~~

GT
F1/77
10/7/0

8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	No

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Patents Form 1/77

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Continuation sheets of this form	—
Description	11 ✓
Claim(s)	2 ✓
Abstract	—
Drawing(s)	10 ✓ 10

10. If you are also filing any of the following, state how many against each item.

Priority documents	—
Translations of priority documents	—
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	—
Request for preliminary examination and search *(Patents Form 9/77)*	—
Request for substantive examination *(Patents Form 10/77)*	—
Any other documents *(please specify)*	—

11. I/We request the grant of a patent on the basis of this application.

Signature Hillgate Patent Services Date 7/7/72

12. Name and daytime telephone number of person to contact in the United Kingdom PAUL HARMAN 020 7704 9997

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Electric Motors for Powering Downhole Tools

The present invention relates generally to downhole pumping systems and, more particularly to a new electric motor for use with a downhole tools such as a pumping system and which does not require a conventional protector.

Electric submersible pumps (ESPs) are widely used throughout the world for recovering subterranean fluids to the earth's surface. For the long term successful operation of such submersible pumping systems, the electric motor is supplied with uncontaminated motor oil. The motor oil not only lubricates the motor, it also cools the motor to prevent overheating. In most submersible pumping systems in use today, this motor oil is partially contained within a device commonly referred to as a motor protector. Conventional motor protectors typically include one or more elastomeric bags. These elastomeric bags provide two important functions: (1) equalizing the fluid pressure within the motor to that in the adjacent wellbore and (2) preventing well fluids and gases from contaminating the motor oil. In regard to the first function, it should be understood that the temperature of the motor oil varies as a result of the intermittent operation of the submersible motor. As the temperature of the motor oil rises, for instance, the oil tends to expand and the pressure within the motor tends to increase. If the motor protector did not include an expandable member, such as the elastomeric motor protector bag, the internal pressure of the motor would increase dramatically. However, the motor protector bag expands and contracts to compensate for the varying liquid volume and to maintain a relatively constant pressure within the motor. In regard to the second function, the motor protector bag provides a degree of isolation

between the motor oil and the well fluids and gases. This isolation helps keep the motor oil clean to increase the longevity of the motor. Most elastomeric motor protector bags prevent many contaminants, such as crude oil, water, brine, and dirt, which may greatly reduce the life of the motor, from entering the motor. As discussed above, in many applications elastomeric motor protector bags perform reasonably well. However, elastomeric bags suffer from several limitations. First, the repeated expanding and contraction of the elastomeric bag can cause the bag to split or crack under certain conditions. Of course, once an elastomeric bag splits or cracks it no longer protects the motor oil from contaminants which are then free to enter and ultimately damage the motor. Second, elastomeric bags tend to lose their elasticity due to various conditions which may be present in a wellbore. Once an elastomeric bag loses its elasticity, it can no longer expand and contract as needed to satisfy the requirements of the motor oil which it contains. Eventually the bag will rupture, leaving the contaminants free to attack the motor. Third, most elastomers cannot survive in environments where the temperature rises above about 400DegF. Above that temperature, most elastomers become brittle causing the bag to break during expansion or contraction. Finally, elastomeric compounds currently used for motor protector bags tend to be relatively permeable as compared to the contaminants within the wellbore fluid. Many wells contain contaminants, such as hydrogen sulfide for instance, which will permeate the motor protector bag and attack the motor. In fact, certain contaminants, such as hydrogen sulfide, also tend to alter the chemistry of certain elastomers, causing the elastomers to harden. Once the elastomer has hardened, the bag eventually breaks. In an effort to combat one or more these problems, the elastomeric material used to fabricate the motor protector bags have been studied and chosen to provide certain advantages.

For instance, certain elastomers may slow the rate at which contaminants such as hydrogen sulfide enter the motor, but they cannot stop the permeation completely. Alternatively, certain elastomers may exhibit an ability to withstand temperatures as high as about 400DegF., but these elastomers tend to have limited elasticity incompatible with the requirements of the motor.

The object of the invention is therefore to provide a new electric motor arrangement for powering downhole tools which avoids these problems with the use of protector bags for protecting motors from the downhole environment.

According to the invention there is provided an electric motor, for powering downhole tools, of the brushless DC type; comprising a stator and a rotor connectable to a rotatable device, a permanent magnet and a series of coiled windings or laminations having a connection to a DC supply, the permanent magnet and the laminations being arranged annually with respect to each other, characterised in that a sleeve is arranged concentrically between the permanent magnet and the laminations.

The laminations are preferably attached to a housing wall on one side and on the opposite side to the sleeve, and the housing wall and sleeve are sealed at each end thereof forming a sealed chamber enclosing the laminations.

The sealed chamber preferably includes a pressure compensation means.

The connection of the windings to a DC supply is preferably enclosed in the sealed chamber.

The sliding seals are preferably arranged at each end of the housing or sleeve with end fittings at each end of the sleeve and housing providing a slidable seal with each end fitting.

The rotor may be connected to the permanent magnet and the stator is connected to the laminations. The rotor is typically connected to a pump.

The housing may be arranged internally of the laminations and forms an internal bore for the passage of well fluids

Several embodiments of the invention will now be described with reference to the following drawings in which :

Fig.1 is a view of the general arrangement of an existing downhole motor used to power a pump;

Fig. 2 is a longitudinal section of a typical prior art motor used in fig. 1;

Fig. 3 is a longitudinal section of a motor according to a first embodiment of the invention;

Fig. 4 is a longitudinal section of the motor of fig. 3 with the rotor removed;

Fig. 5 is a longitudinal section of a motor according to a second embodiment of the invention;

Fig. 6 is a longitudinal section of a motor according to a third embodiment of the invention;

Fig. 7 is a transverse section through the motor of fig. 6, and

Fig.8 is a longitudinal section of the motor of figs. 6 and 7 with the rotor removed.

Fig. 9 shows a side view of another embodiment of the modular motor

Fig. 10 shows a side view of the several sections of this embodiment of the modular motor installed into a housing

Figs. 11 and 12 show a spreadsheet and graph respectively showing the calculated horsepower for various diameters and speeds

Where equivalent components appear in different embodiments, the same designating numeral will be used.

Referring initially to FIG. 1, a pumping system is illustrated and generally designated by a reference numeral 10. The pumping system 10 is shown located in a well bore 12 that has been created within a subterranean formation 14. Although not specifically illustrated, it is well known that the well bore 12 contains fluids and gases from the surrounding formation 14 and that the pumping system 10 is adapted to be submerged in these fluids

and gases within the well bore 12. The pumping system 10 is typically part of a production tubing string 16 and is responsible for pumping fluids and/or gases from the well bore 12 to the surface of the Earth. The pumping system 10 includes a pump 18 that is driven by a motor 20. The motor 20 is advantageously an electric motor. The motor 20 contains motor oil (not shown) which lubricates and cools the motor 20. A motor protector 22 is coupled to the motor 20. The motor protector 22 contains a portion of the motor oil, and it functions to keep the motor oil free from contaminants and to maintain a relatively constant pressure within the motor 20. Although the motor protector 22 is illustrated in this example as being coupled between the pump 18 and the motor 20, it should be understood that other arrangements may be suitable.

Figure 2 shows a longitudinal section through a conventional ESP motor. These are induction motors which are essentially rotary transformers in which power transfers to the secondary coil, on the rotor, which results in rotation of a mechanical load. The tolerance between the rotating and non rotating components needs to be quite close. The magnetic field is set up in the stator's main inductance (the magnetizing inductance). Most of the input power couples to the rotor secondary winding and thus the load. Typically, three windings are used, driven by utility power in phases separated by 120 degrees. The result is a magnetic field that rotates around the motor axis at power frequency divided by the number of poles. Because there are windings on both rotating and non rotating components and the close tolerance between the rotor and stator, they have always had a common oil bath.

In figs. 3 and 4 we can see the first embodiment of the invention, using a brushless DC motor 30 as opposed to the AC induction motors of the prior art, in these motors permanent magnets 31 are fitted to the rotor 32, and as a consequence the clearance between the rotor 32 and the motor laminations 33 can be larger than that of an induction motor. In this embodiment a sleeve 34 (of non-magnetic stainless steel or a non-magnetic composite material tube) is arranged between the rotor 32 and the motor laminations 33. This enables static O ring seals 38, 39 to be arranged between the sleeve 34 and the end fitting 35 isolating the lamination and windings section of the motor from the rotating sections of the motor and pump. As can best be seen from fig. 4 a sealed annular chamber 36 is created between the outer housing 37 and the inner sleeve 34 in which the motor laminations 33 and connections are located. The sealed chamber is defined at each end by end fittings 35 and corresponding O rings seals 38, 39 are provided on the internal wall of the housing 37 and the external wall of the sleeve 34. The seals do not need to seal during rotational movement but merely to seal against a degree of lateral movement required to compensate for pressure and temperature variations. These seals are therefore much more reliable and less costly than rotating seals. This sealed chamber is completely isolated from the oil well environment.

This provides the following significant advantages

1. No rotating seals are required to isolate the water and gas sensitive laminations, electrically insulated windings and electrical contacts.

2. Hydrogen sulfide cannot enter the motor oil past the static seal, so scavengers need not be added to the motor oil. The lack of scavengers is advantageous for various reasons. For instance, motor

oil additives, such as scavengers, tend to increase the cost of the motor oil. Also, such additives typically reduce the effectiveness of the motor oil in performing its primary functions of cooling and lubricating the motor. Finally, it has been found that many such scavengers reduce the dielectric constant of the motor oil. In the event that insulation that protects windings and other conductors within the motor fails, a motor oil having a high dielectric constant is advantageous because it will so reduce the likelihood of arcing between exposed conductors that may damage the motor.

3. A simple oil expansion and contraction system can be used which is well proven and understood, and again only has non-rotating seals.

Referring now to fig. 5 a modification of the embodiment in figs. 3 and 4 is shown in which the sealed chamber 36 includes a hydrostatic and temperature/pressure compensation means 40 which allows for the effects of the large pressure and temperature changes that the sealed chamber will be subject to ensuring that no pressure difference builds up which could damage the seals 38, 39, housing 37 or sleeve 34. The compensation means includes a laterally movable plug 41 in sealing engagement with the inside walls of the chamber 36 which forms a compensation chamber 42 having a vent hole 43 through the housing 37 to outside of the motor.

Referring now to figs. 6 to 8 a further embodiment is shown in which the rotor is arranged outside the laminations allowing flow of fluids through the empty bore of the motor. The same reference numerals in all embodiments are used for corresponding elements even though the arrangement of them is different. The rotor and the permanent magnet 31 is arranged on the

outside of the laminations 33 and the laminations 33 are similarly enclosed in a stainless steel sleeve arranged between the permanent magnet and the laminations 33. The laminations are arranged in annular formation around an internal housing 50 through which pumped fluids flow. The sealed chamber is formed between the internal housing and the sleeve encapsulating the laminations 33 and protecting them from an well fluids. The sealed chamber contains a pressure compensation means 52 which serves to adjust to any pressure changes outside the motor through vent hole 43. This can be seen best from fig. 8 which shows this embodiment with the rotor removed.

Figures 9 to 10 show details of another embodiment of the modular electrical motor. As in the previous embodiments, a sleeve 34 (of non magnetic stainless steel or a on magnetic composite material tube) is arranged between the rotor 32 and the motor laminations 33. This enables static O ring seals 38, 39 (visible in figure 10) fitted to an end fitting 35 to be arranged between the sleeve 34 and the end fittings 35, 55, isolating the lamination and windings section of the motor from the rotating sections of the motor and pump. As can best be seen from fig. 9 a sealed annular chamber 36 is created between the outer casing 37 and the inner sleeve 34 in which the motor laminations 33 and connections are located. The sealed chamber is defined at each end by end fittings 40 and corresponding O rings seals 38, 39 are provided on the internal wall of the casing 36 and the external wall of the sleeve 34. The seals on the end fitting 35 are not subjected to rotation, so do not need to be rotationally effective seals but merely to seal against a degree of lateral movement required to compensate for pressure and temperature variations. These seals are therefore much

more reliable and less costly than rotating seals. This sealed chamber is completely isolated from the oil well environment.

The rotor is maintained in position in the stator by permanent magnet bearings 47, which act on portions 48 of magnetically susceptable material (e.g. stainless steel) present on the rotor, which constrain the motor against lateral movement along the motors axis, and the rotor's axis aligned with the stator's axis.

As in the previous embodiments, this configuration provides the previously discussed significant advantages with regards to the isolating the gas sensitive laminations, electrically insulated windings and electrical contacts without recourse to rotating seals, the need for scavengers added to the motor oil is obviated since contamination by hydrogen sulphide is eliminated, and simple oil expansion and contraction systems are well proven and understood, and again only has non-rotating seals.

As shown in figure 10, the several motor modules 60 can be arranged in a series (and the windings can be electrically connected in series); three motors are shown here. A modular motor enables a more efficient and productive construction. The modules can be installed inside a simple housing 37 reducing the cost and complexity of the entire system. When arranged in such a series, only a pair of o-rings 38 and 39 at either end of the series are required. The rotors may be torsionally coupled, or a single rotor extending through the modular system may be used.

While the invention may be susceptible to various modification and alternative forms, specific embodiments have been shown by way of

example in the drawings and have been be described in detail herein. However, it should be understood that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the following appended claims.

Referring to figs. 11 and 12, the horsepower developed by the motor is calculated to vary as shown according to the diameter and speed of a motor, in this calculation the motor being composed of three 1.35m active length motor modules.

Claims

1. An electric motor, for use with downhole pumping systems, of the brushless DC type; comprising a stator and a rotor connectable to a rotatable device, a permanent magnet and a series of coiled windings or laminations having a connection to a DC supply, the permanent magnet and the laminations being arranged annually with respect to each other, characterised in that a protective layer is provided between the laminations and the permanent magnet.

2. An electric motor according to claim 1, characterised in that the protective layer is in the form of an non-magnatisable sleeve.

3. An electric motor according to claim 1, characterised in that the laminations are attached to a housing wall on one side and on the opposite side to the sleeve and the housing wall and sleeve are sealed at each end thereof forming a sealed chamber enclosing the laminations.

4. An electric motor according to claim 3, characterised in that the sealed chamber includes a pressure compensation means.

5. An electric motor according to claim 3, characterised in that the connection of the windings to a DC supply is enclosed in the sealed chamber.

6. An electric motor according to claim 3, characterised in that sliding seals are arranged at each end of the housing or sleeve providing a slidable seal between the housing and sleeve.

7. An electric motor according to claim 3, characterised in that sliding seals are arranged on end fittings at each end of the sleeve and housing providing a slidable seal with each end fitting.

8. An electric motor according to claim 1, characterised in that the rotor is connected to the permanent magnet and the stator is connected to the laminations.

9. An electric motor according to claim 1, characterised in that the rotor is connected to a pump.

10. An electric motor according to claim 1, characterised in that the housing is arranged internally of the laminations and forms an internal bore for the passage of well fluids.

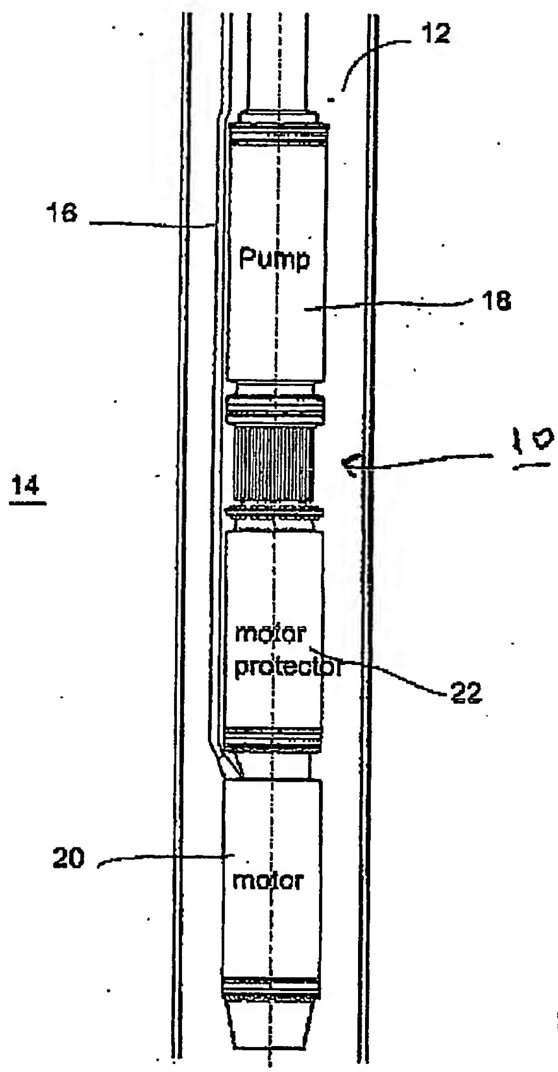

Figure 1

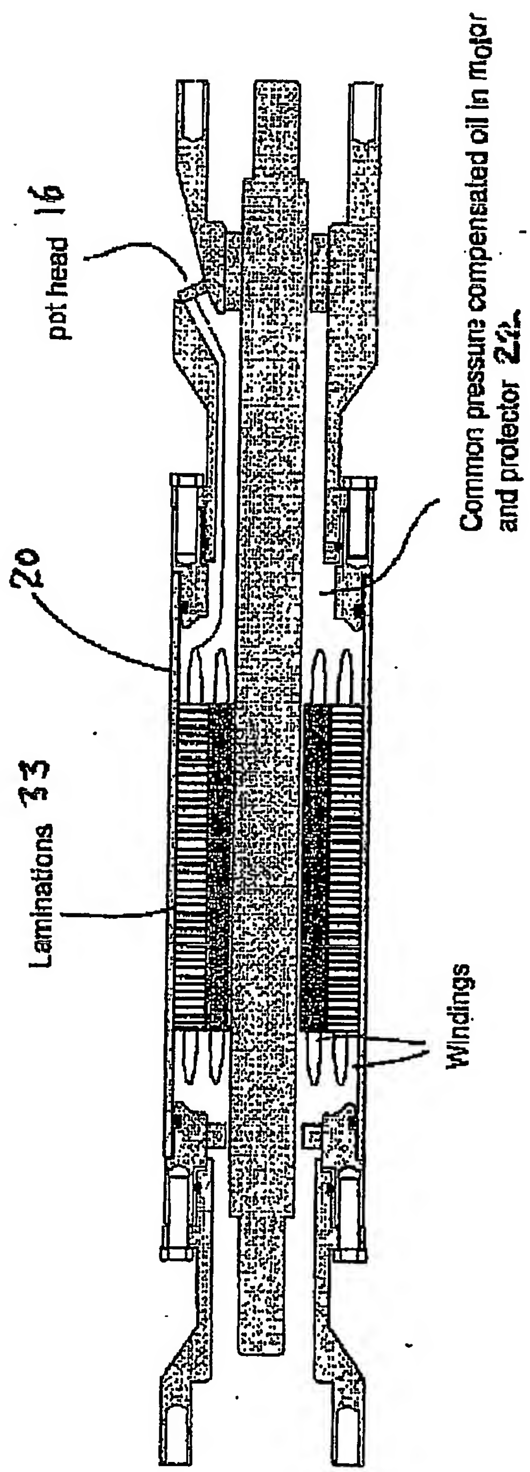
pot head 16
20
Laminations 33
Common pressure compensated oil in motor and protector 22
Windings

Figure 2

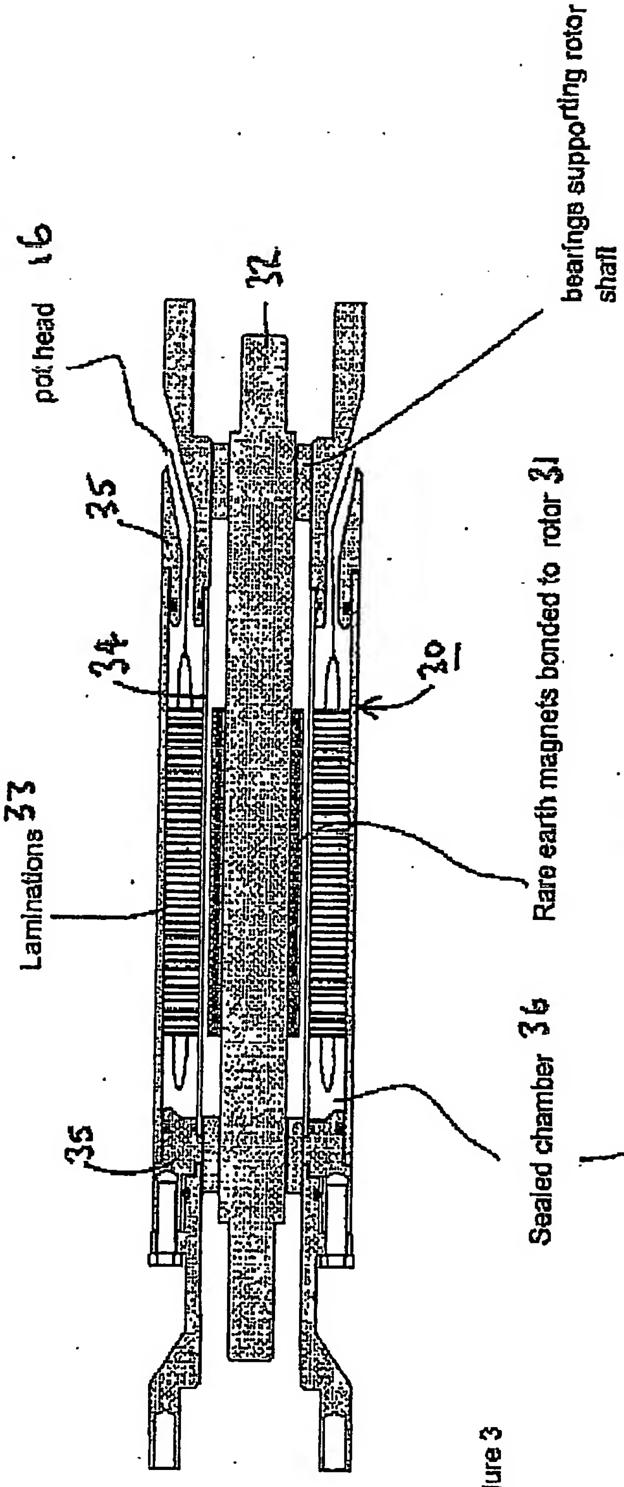

Figure 3

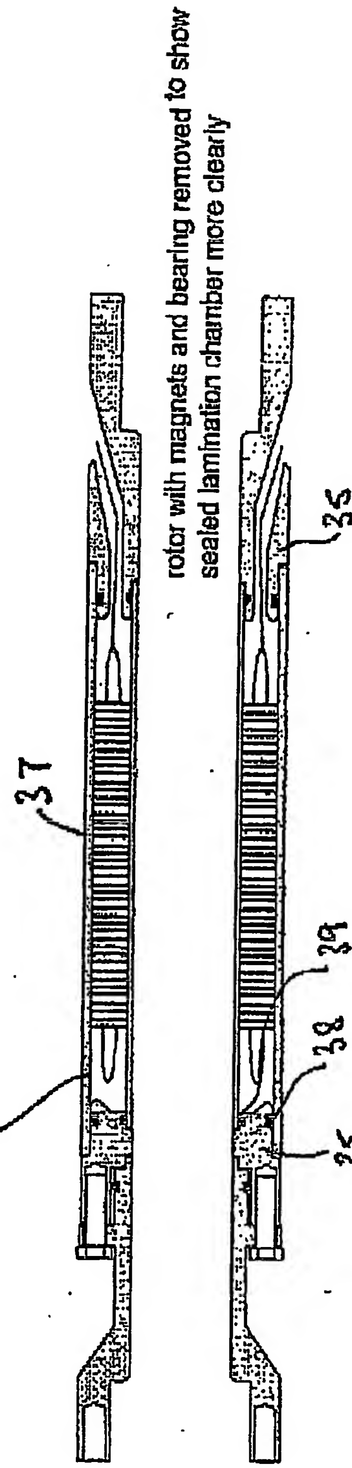

Figure 4

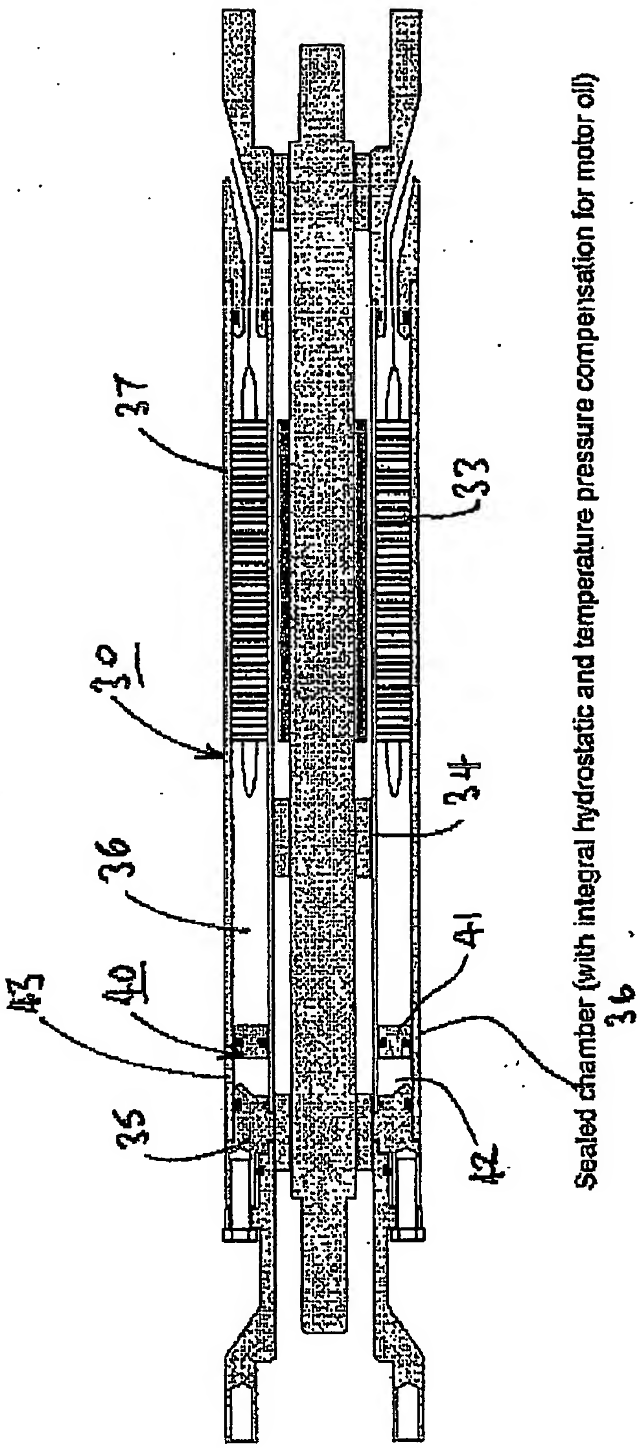
37
33
30
34
36
41
40
43
35
42
Sealed chamber (with integral hydrostatic and temperature pressure compensation for motor oil)
36

Figure 5

Laminations on the inside, to keep cool as the production fluid is pumped up the inside of the motor

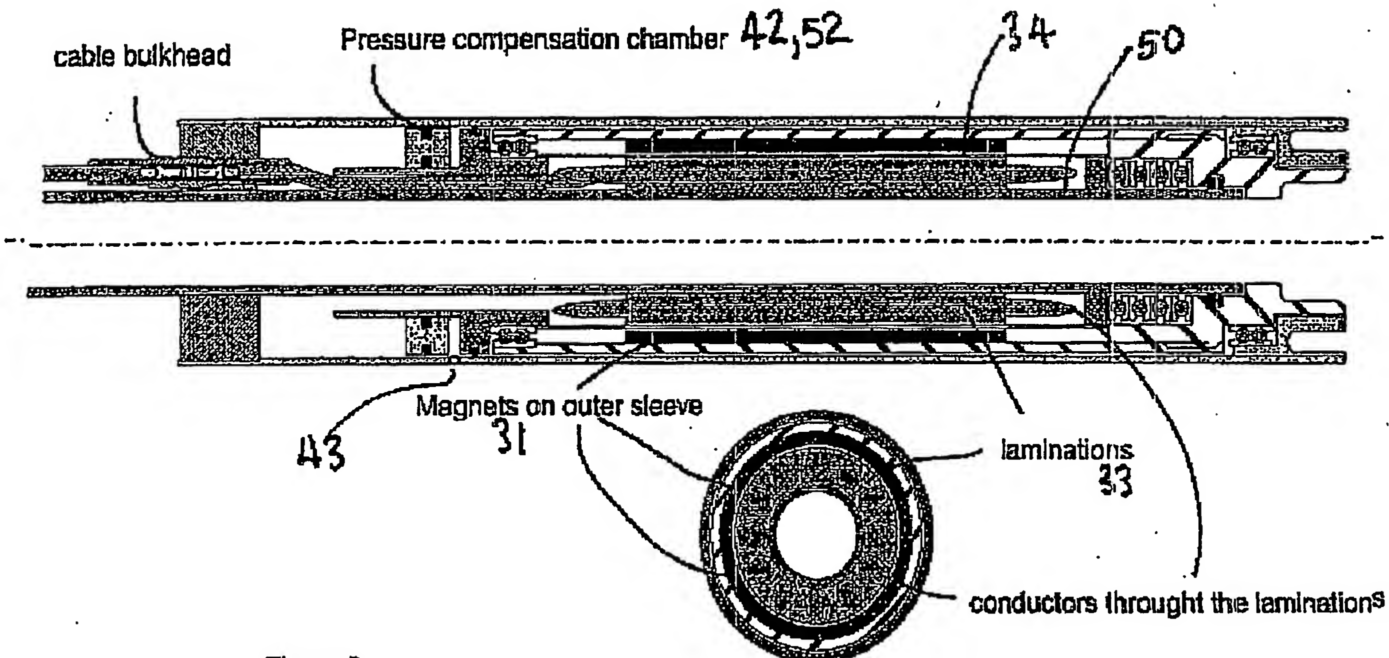

Figure 6

Figure 7

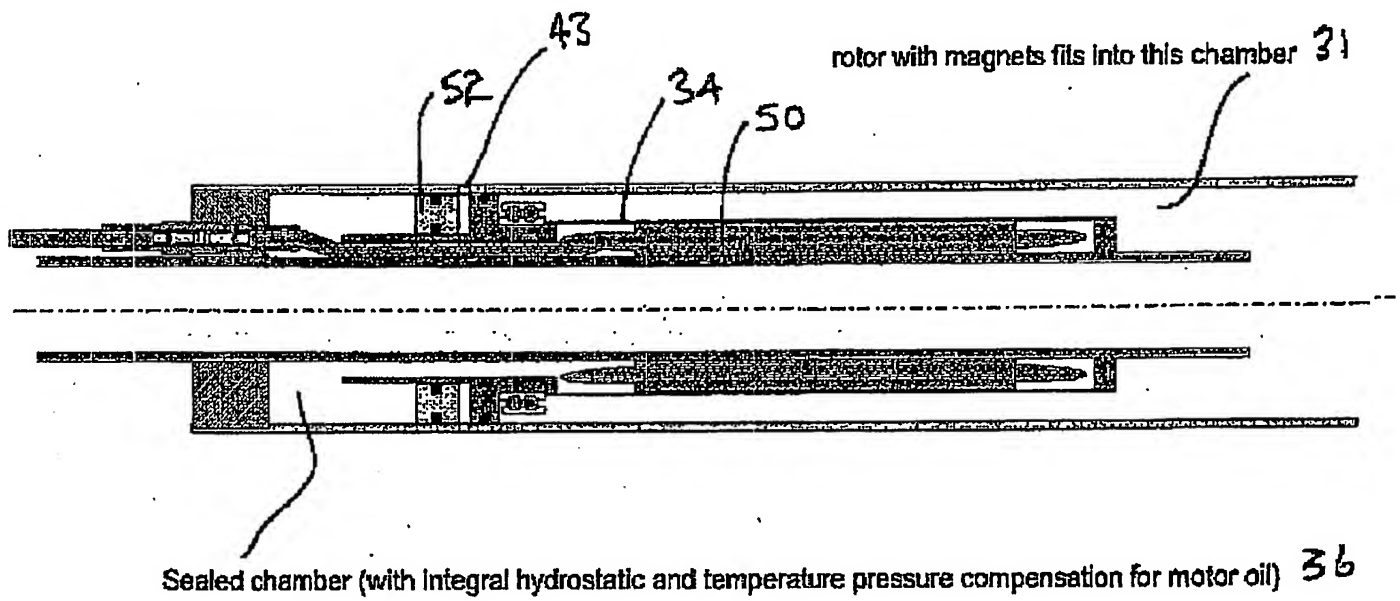
rotor with magnets fits into this chamber 31
43
52
34
50
Sealed chamber (with integral hydrostatic and temperature pressure compensation for motor oil) 36

Figure 8

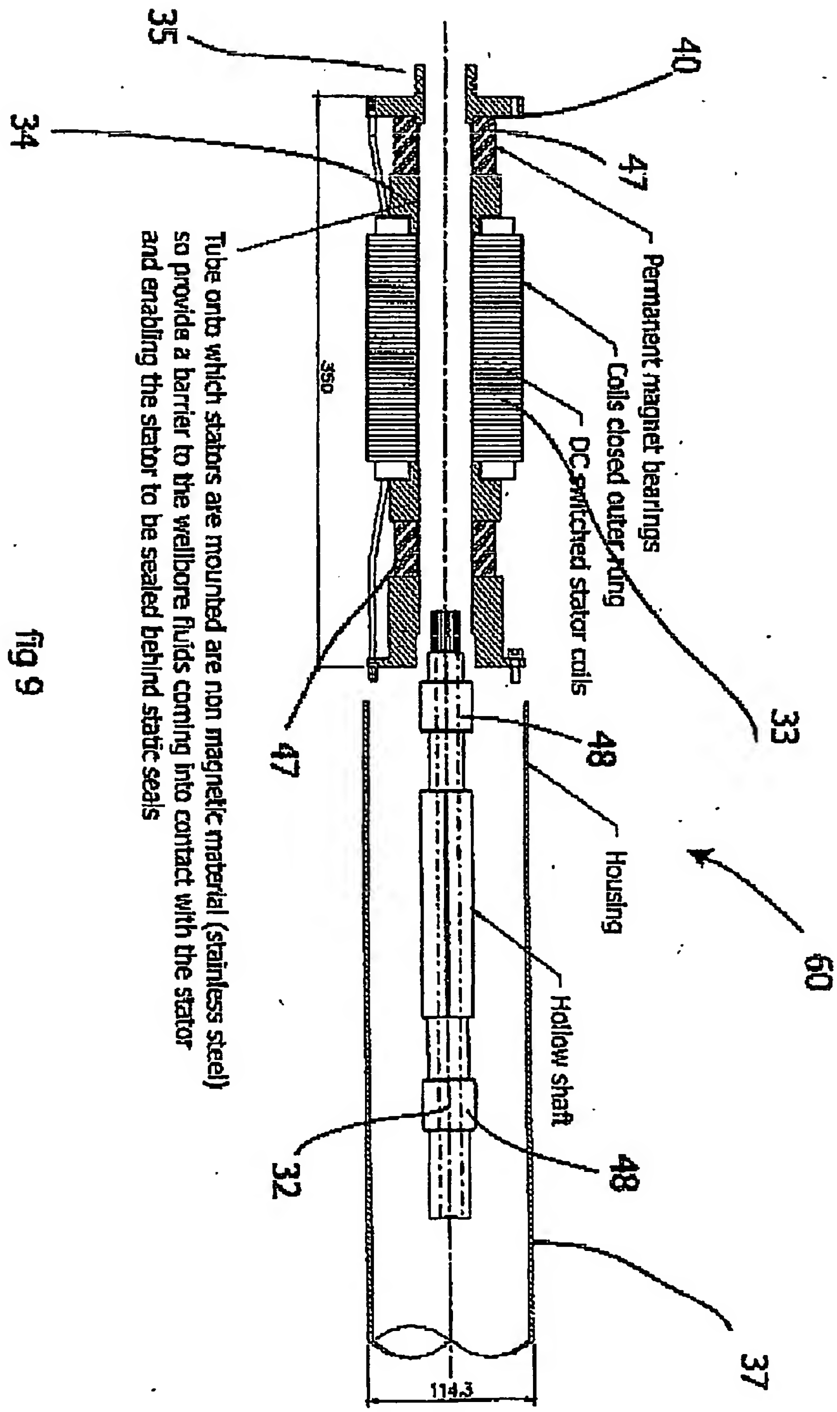
40
35
34
47
Permanent magnet bearings
Coils closed outer ring
DC switched stator coils
33
350
Tube onto which stators are mounted are non magnetic material (stainless steel) so provide a barrier to the wellbore fluids coming into contact with the stator and enabling the stator to be sealed behind static seals
47
48
Housing
60
Hollow shaft
32
48
37
114.3

fig 9

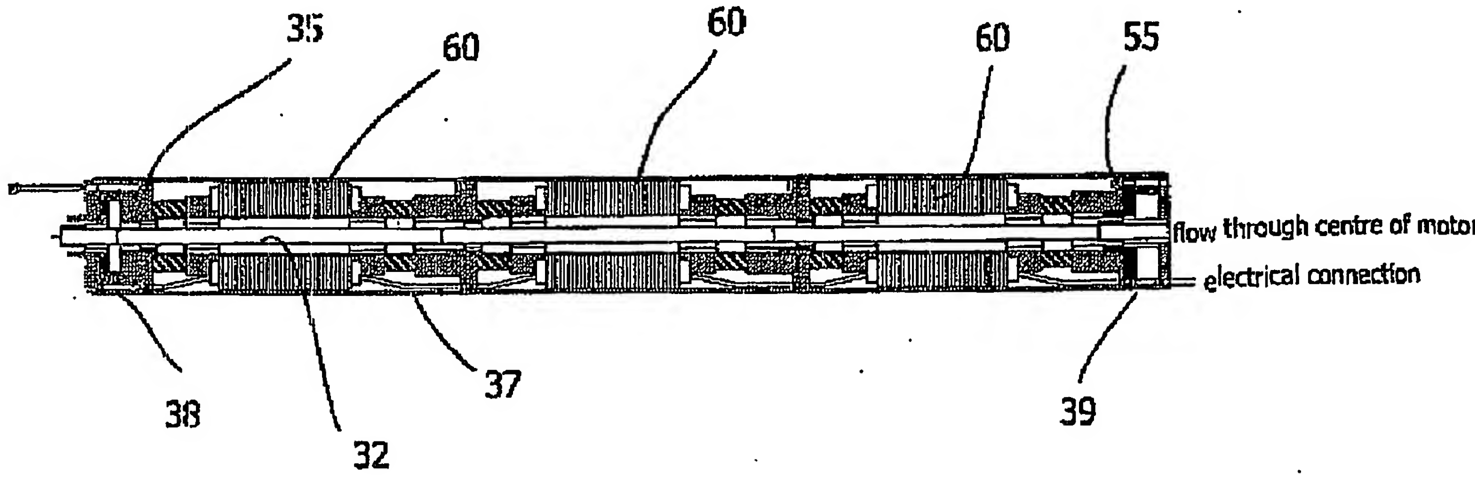
35
60
60
60
55
flow through centre of motor
electrical connection
38
32
37
39

fig 10

Horse Power Permanent Magnet Motor

rpm	3.12" OD motor	3.50" OD Motor	3.75" OD Motor	4.00" OD Motor
500	23	32	39	47
1000	45	64	78	95
3000	136	193	234	284
7200	327	464	562	683
9000	409	580	703	853

NOTES:

For long term endurance a derating would be required
These figures refer to motors operating in fluids up to 200 C
3 motor core sections, each section 1.35M active length

fig 11

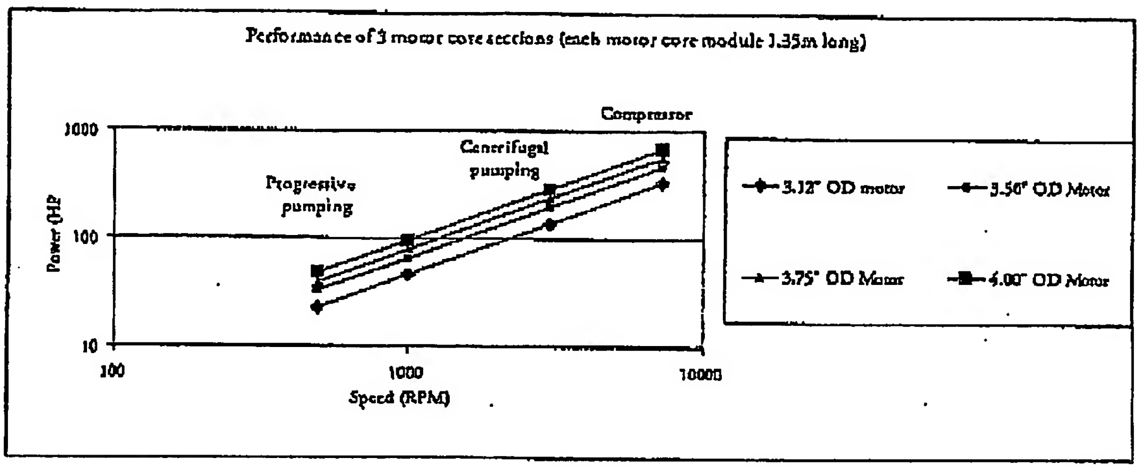
Performance of 3 motor core sections (each motor core module 1.35m long)
Compressor
Centrifugal pumping
Progressive pumping
1000
100
10
Power (HP)
100
1000
10000
Speed (RPM)
3.12" OD motor
3.50" OD Motor
3.75" OD Motor
4.00" OD Motor

fig 12

PCT Application
GB0304009